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NOTES ON GROWTH AND REPRODUCTION OF THE SLIMY SALAMANDER PLETHODON GLUTINOSUS

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INTRODUCTION

Although the slimy salamander, *Plethodon glutinosus glutinosus*, is one of the most widely distributed, abundant, and conspicuous of all the plethodontids, relatively little is known about its life history, especially its reproduction and growth. In his excellent comprehensive accounts of New York salamanders, Bishop (1941) devotes eight pages to the reproduction and growth of *Hemidactylium scutatum* and *Plethodon cinereus*, but only three and a half pages to those topics in his discussion of *P. g. glutinosus*. In other words, he has more than twice as much to report on each of those two plethodontid forms as on *P. g. glutinosus*.

The abundance of the slimy salamander in the mountains of western Virginia afforded us ample opportunity to collect and study it during our 1948 sojourn at Mountain Lake Biological Station, Giles County, Virginia. We are greatly indebted to Director Bruce D. Reynolds, who put the facilities of the Station at our disposal and co-operated in every other possible way. We are likewise indebted to Mr. Robert F. Inger and Dr. Jules H. Last, who gave invaluable advice and help on statistical treatment of data.

MATERIAL AND METHODS

A series of 125 specimens of *Plethodon g. glutinosus* was collected in western Virginia (124) and in West Virginia (1). All material was caught and preserved within a period of a little less than eight

weeks, as shown by the accompanying table. The Virginia localities given in the table are High Knob, a mountain south of Norton, and in Wise County; Mountain Lake Biological Station, in Giles County; Poor Mountain, a few miles southeast of Roanoke; a Rockbridge County site on the Blue Ridge Parkway, 11.4 miles north of the intersection of U. S. Route 60 and the Parkway. The single West Virginia locality is East River Mountain, five miles east of Bluefield.

SUMMARY OF COLLECTING SITES AND DATES
(*Measurements of Specimens in Millimeters*)

Localities and altitude in feet	Date collected	Males		Females		Juveniles	
		No.	Range*	No.	Range*	No.	Range*
High Knob (4000–4050)	July 27	9	45–67	6	41–63	12	22–35
Mt. Lake Biol. Station (3800–4000)	June 27–30	6	54–61	2	37–66	3	29–34
	July 15–20	4	51–71				
	July 31–Aug. 5	23	35–69	25	35–71	17	22–29
Poor Mt. (3400–3600)	Aug. 19	6	45–67	4	40–75	5	15–29
Blue Ridge Parkway (3150–3300)	Aug. 9			2	48–80		
East River Mt. (3375)	July 28			1	69		

*Snout-vent.

Collecting was done by daylight and individuals of all sizes were taken as encountered. Specimens were preserved in formalin soon after capture and transferred to alcohol later.

The anterior angle of the vent was used in making the snout-to-vent measurement, the dimension to which the term "length" is applied in this paper. Tail length was obtained by subtracting the snout-to-vent measurement from the total length. Snout-to-vent measurements were taken originally to 0.1 mm. with Vernier calipers. In giving measurements, especially in the histograms and graph, the decimals from 0.1 through 0.4 were dropped and those from 0.5 through 0.9 were raised to the next whole number; a few exceptions have been made in dealing with the smallest specimens. Measurements of total length were taken to the nearest millimeter by stretching the specimen along a meter stick.

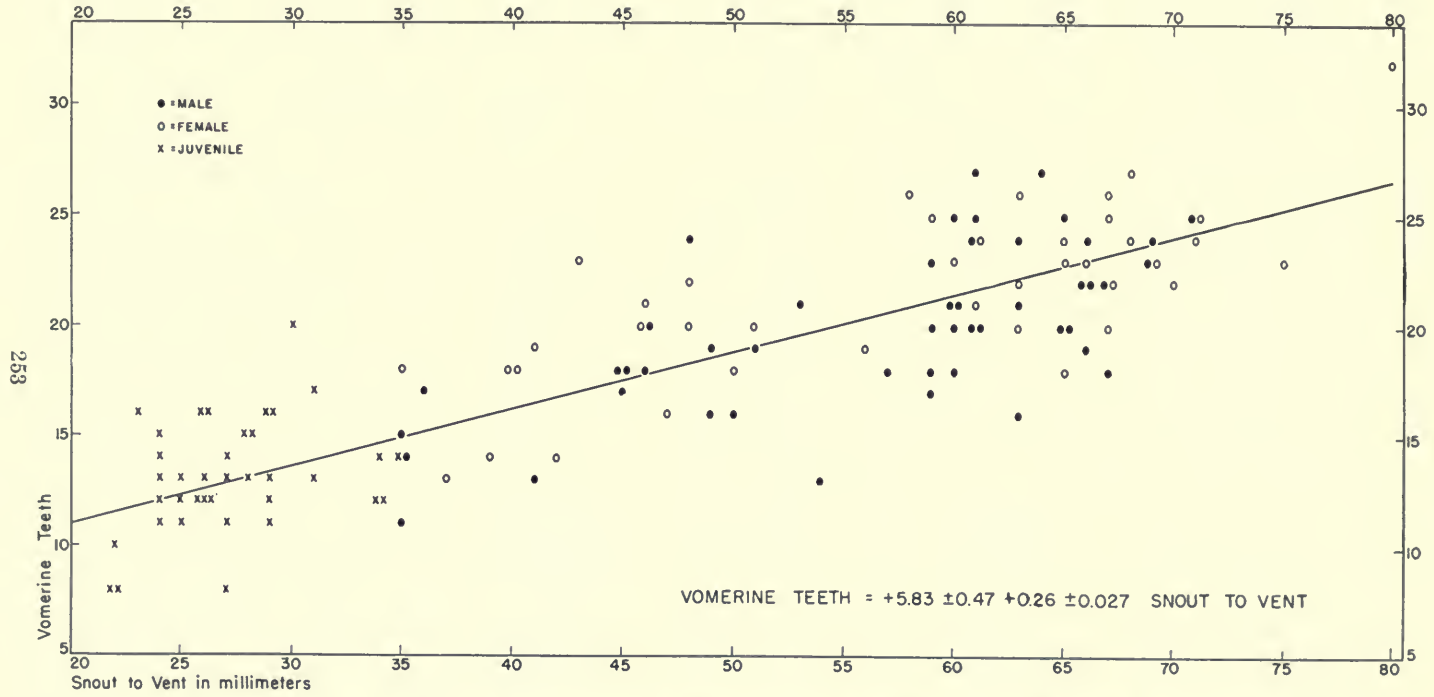

FIG. 60. Number of vomerine teeth plotted against snout-to-vent length in juveniles, males, and females.

NUMBER OF VOMERINE TEETH CORRELATED WITH LENGTH

Since the number of vomerine teeth in salamanders is commonly used as a character in taxonomy, counts were made on the entire series of 125 individuals to determine whether there is any sexual difference or ontogenetic change in the counts. Mittleman (1947 and 1948) got largely negative results in his similar study of a plethodontid (*Manculus quadridigitatus*) and of an ambystomid (*Ambystoma macrodactylum*).

Perusal of our data shows that only 38 per cent of the specimens have the same number of teeth on both sides. Because of this, the sum of the right and left counts has been used in all subsequent calculations. It is interesting to note that only the largest specimen has as many as seventeen teeth on one side, whereas the two smallest have four on each side. No specimen has a lower count and only one other has as few as four on either side. This one measures 27 mm. from snout to vent.

Figure 60 shows the distribution of counts in the entire series. The difference between adults and juveniles is great enough to interfere with identification of the latter by vomerine counts, whereas that between the sexes is too little to be significant and is perhaps only a reflection of the slightly larger average size of the female.

MALE SECONDARY SEX CHARACTERS CORRELATED WITH LENGTH

Mental Gland.—Since all males above a certain size (58 mm. snout to vent) have a mental gland (fig. 61), we assume that its absence in nearly all the smaller ones is due to immaturity rather than to season. The mental gland is occasionally evident in specimens only 45 to 49 mm. long.

Unfortunately, the actual mating season has not been directly determined, but the following data are of interest. Bishop (1941, p. 224) found New York males with sperm-packed vas deferens in October, while those taken from May through August had spermless vas deferens. Kezer (1948) dissected series from the same part of this state and reported that in most of those taken during late autumn the caudal end of the testis consisted largely of spermatocytes in pachytene; in early March these caudal spermatocytes were in active spermatogenesis; by the first part of July the spermatogenic wave had completed its movement through the testis. Humphrey (1925) and Burger (1937, p. 467) are in essential agreement with Bishop and Kezer.

Cloacal Gland Papillae.—Figure 62 shows that the cloacal papillae are evident in all males that measure more than 49 mm. from snout to vent. Two males were unusual in having grooves in the cloacal lips and one was precocious in having both papillae and a moderately distinct mental gland at 45 mm. (No. 402). The cloacal papillae are thus seen to be more useful in sex determination than is the mental gland. This fact was confirmed by superficial examination

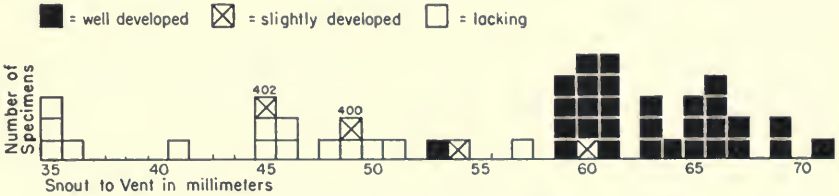

FIG. 61. Mental gland correlated with snout-to-vent length. Identical specimens are indicated by the same numbers (402, 400) in figures 61 and 62.

of the testes, a method that Burger (loc. cit.) has found to be reliable. No. 402 is also the smallest male with bulbous testes.

Taking 49 mm. as the size at which sexual maturity is usually reached in this sex, the mean length of the thirty-seven males

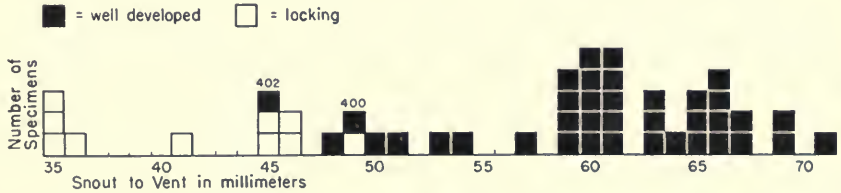

FIG. 62. Cloacal gland papillae correlated with snout-to-vent length. See legend of figure 61.

measuring 49 mm. and over is 61 mm. $\pm$0.91 from snout to vent, that of all forty-eight males 57 mm. $\pm$1.42.

CONDITION OF OVARIES AND OVIDUCTS CORRELATED WITH LENGTH AND SEASON

Gross examination of the ovaries and oviducts enabled us to divide the females into mature and immature individuals with a sharp line of demarcation falling at 57 mm. snout-to-vent measurement (fig. 63). The mean length of the twenty-four mature females is 66 mm. $\pm$1.01, that of all forty of this sex 57 mm. $\pm$1.89.

The mature females themselves (excepting a pathological one that has been omitted) fall into: (1) a group of eleven individuals in which the ovaries are packed with large yolk-laden eggs relatively uniform in size, and the oviducts are swollen and convoluted; (2) a group of twelve in which the ovaries are not packed, the eggs are of various sizes, and the oviducts are not swollen and convoluted (fig. 63). The first group obviously is composed of females ready to lay, whereas the second is considered to include those females

FIG. 63. Condition of ovaries and oviducts correlated with snout-to-vent length. Squares with diagonals indicate undeveloped ovaries; solid squares indicate packed ovaries and swollen, convoluted oviducts; open squares, ovaries not packed and oviducts not swollen or convoluted.

that laid a few weeks previous to the date of capture. A post-laying lapse of time is indicated by the condition of the oviducts as well as by the fact that females of *P. g. glutinosus* guard their eggs (Noble and Marshall, 1929, p. 6) and would not be abroad during the hours of daylight when all our collecting was done.

Figure 64 correlates the condition of the ovaries with the date of capture and shows that about half the individuals taken from July 27

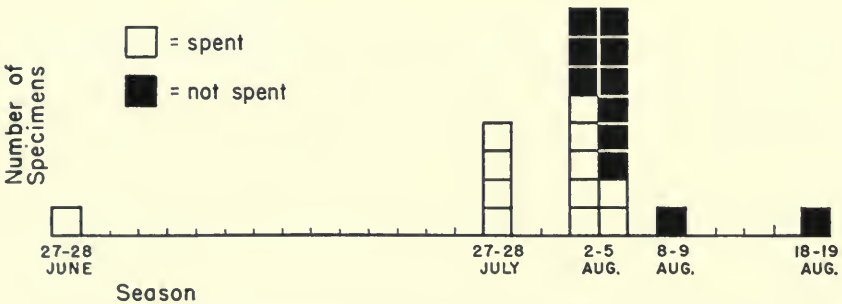

FIG. 64. Condition of ovaries and oviducts correlated with season.

through August 9 were spent. From this we conclude that the height of the laying season occurs at this time. This is in agreement with the discovery of Noble and Marshall (loc. cit.) in caves of northern Arkansas: eggs in cleavage on August 17 and others with well-developed embryos on September 3. The only other *glutinosus* eggs

on record were found by Fowler (1940) in Hampshire County, West Virginia, on June 3 (altitude not stated). They presumably were in an early stage of development since no embryos are mentioned. As pointed out by Fowler, these three records indicate an extensive breeding season. Our capture of a spent female as early as June 27 or 28 and of one with packed ovaries as late as August 18 or 19 confirms this conclusion.

Bishop (1941, pp. 224, 226; 1943, p. 253) concluded that in New York the eggs are deposited before May or possibly early in that month, but it scarcely seems possible that this species would breed at one season in the lowlands of central and southern New York and at another in the high mountains of Virginia; in fact, one would expect coincidence of breeding seasons in these two areas.

NUMBER OF OVARIAN EGGS

Counts of the large eggs in the right and left ovaries of eleven females show no appreciable difference, the range and mean for the right being 9 to 16 and 12.1 $\pm$0.69, for the left 7 to 20 and 11.3 $\pm$1.01, and the mean for the combined counts 23.4 $\pm$1.42. The largest female held the greatest number of eggs (33), one of the three smallest the lowest (17).

The number of eggs in the three clutches that have been discovered *in situ* are 10, 18 and "about 15" (Noble and Marshall, 1929, p. 6; Fowler, 1940). Since a few large eggs are found in the spent females it is not surprising that the dissected females held more eggs than the nests. Even if all the large eggs were laid, there would probably be some post-laying loss.

SEXUAL DIMORPHISM IN LENGTH

Bishop (1941, p. 219; 1943, p. 251) presents data indicating a greater total length for the adult male, whereas Orton (1946), after measuring extensive series of Pennsylvania specimens, concludes that the female is the larger.

In order to analyze the situation more closely we have studied: (1) relative tail and snout-to-vent lengths in the sexes expressed in percentage; (2) relative variability of these lengths; (3) relative snout-to-vent lengths in the sexes. Snout-to-vent length of 58 mm. in the female has been taken as the minimum for a mature individual; the corresponding datum for the male is 49 mm.

The following table indicates a lack of sexual dimorphism in tail length.

TAIL LENGTH CORRELATED WITH LENGTH FROM SNOUT TO VENT

Sex	No.	Tail/Snout-Vent Length (%)	
		Extremes	Mean
Male	24	92–138	117
Female	15	95–135	120

The relative variability of tail lengths compared with that of snout-to-vent measurements proves to be statistically insignificant, as shown by the accompanying table.

RELATIVE VARIABILITY OF TAIL AND SNOUT-TO-VENT LENGTHS

Length	Range	Mean	Coef. of Var.
		Twenty-four Males	
Tail	56–92	72±1.81	12.32±1.78
Snout-vent	49–71	62±1.14	9.12±1.32
		Fifteen Females	
Tail	55–90	79±2.01	9.86±1.80
Snout-vent	58–80	66±1.50	8.84±1.61

The differences between the coefficients of variation in the males is 3.20 ±2.22 (P=0.14), in the females 1.02 ±2.41 (P=0.68).

Figure 65 shows that in the snout-to-vent dimension the sexes are nearly equal, with the female very slightly longer.

In view of the very slight sexual dimorphism in snout-to-vent length, the lack of it in tail length, and the procedures used by Orton and Bishop, it is little wonder that they arrived at different conclusions.

The snout-to-vent length was by far the more satisfactory measurement in the study of our series because about one-third of the adults had truncated or obviously regenerated tails, and a few others had suspiciously short though not certainly incomplete ones. Before taking total lengths the series had to be carefully picked over and greatly reduced in size. This difficulty is obviated by using the snout-to-vent dimension.

BREEDING AGE

When the series of 125 specimens is arrayed on a histogram by length (snout-to-vent), clearly distinct age groups are not evident (fig. 65), possibly because of the extended laying season. However, one can discern three groups, the first two of which probably represent specimens in their second and third seasons, i.e., the first and second summers after the one in which they were hatched. It is unlikely that any young of the year are included in our series, since

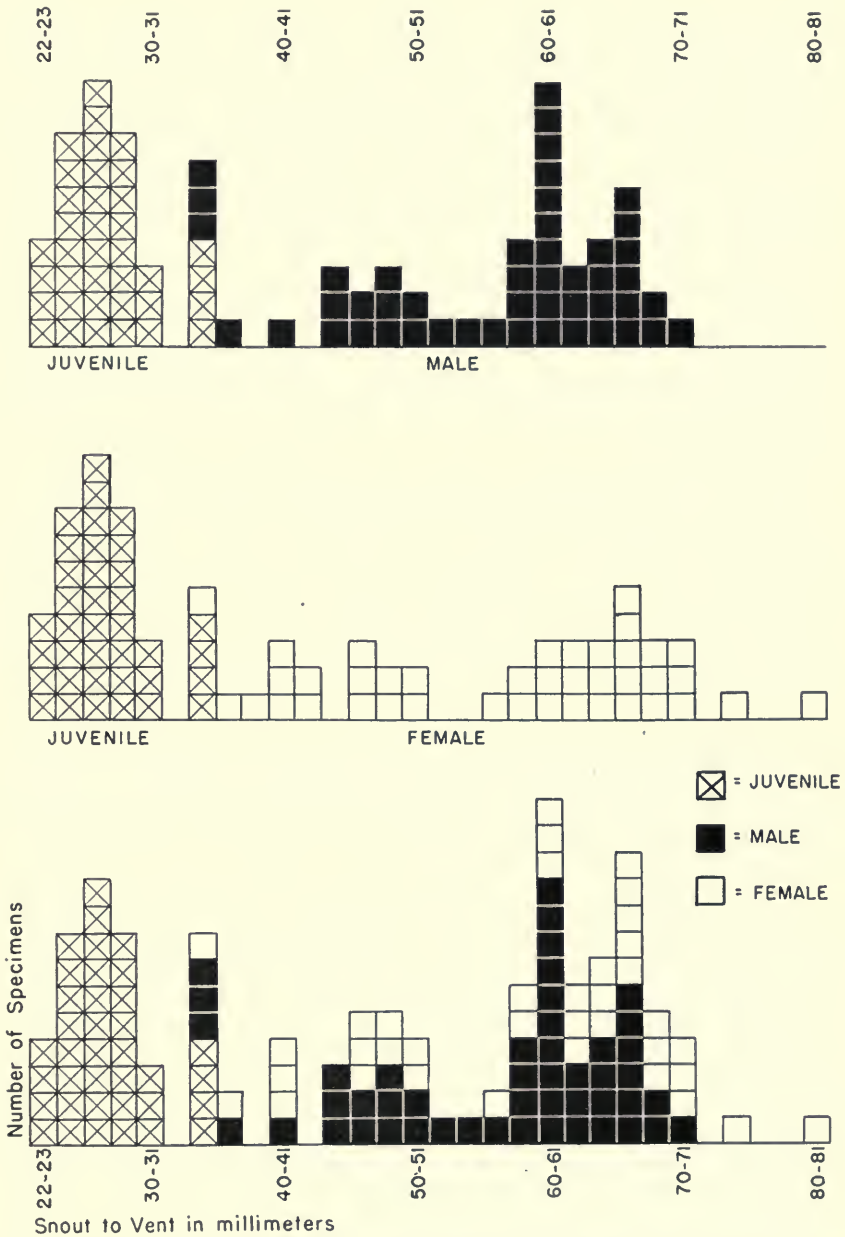

FIG. 65. Size (snout to vent) distribution of juveniles and males (top), juveniles and females (middle), juveniles, males, and females (bottom).

the four smallest individuals measure from 42.2 to 45 mm. in total length and the well-pigmented larva measured by Noble and Marshall (1929, p. 9) was only 16 mm. from tip to tip. The four smallest specimens, moreover, were collected from July 27 to August 2, inclusive, and therefore as hatchlings could not have had much time for growth. Bishop (1941, p. 226) records three specimens taken July 10 to 19, inclusive, as 30 to 34 mm. in total length and reasonably considers them young of the year.

When the sexes are considered and plotted separately (fig. 65), and the fact is recalled that the females 58 mm. long and longer are adult, it becomes evident that the third and larger group is made up of adults. From these data we tentatively conclude that the female has matured by the fourth season of life, when just or not quite three years old.

Comparison of the males with the females (figs. 61–63 and 65) indicates that males develop at about the same rate as the females, but reach maturity at a slightly smaller size. This comparison is not pushed far because the gonads are its basis in females, whereas two secondary sexual characters are the chief basis in males, the gonads having been but superficially examined.

SUMMARY

A statistical study was made of reproduction, growth, and other aspects of the biology of *Plethodon g. glutinosus*. A series of 125 specimens collected at high altitudes in western Virginia and adjacent West Virginia was used.

The number of vomerine teeth increases with age from about 13 in juveniles a year old and older to about 22 in adults. Only counts of adults and near adults should be used in taxonomic studies. There is no appreciable sexual difference in number of vomerine teeth.

Considering the presence of a mental gland as evidence of maturity, all males measuring more than 58 mm. from snout to vent are mature, and a few individuals mature when much shorter. Cloacal gland papillae are evident in all males measuring more than 49 mm. from snout to vent, and in an occasional individual a few millimeters shorter. These papillae are a better means of sex determination than is the mental gland.

Examination of ovaries and oviducts indicates that the line dividing mature from immature females falls at 57 mm. $\pm$1.89 (snout to vent). The mean length of mature females is 66 mm. $\pm$1.01.

The laying season at high altitudes in western Virginia and adjacent West Virginia extends at least from the last part of June through most of August, with the peak occurring from late July through early August. The season probably includes all of June and much of September.

The mean number of mature eggs per female determined by dissection is 23.4 ±1.42 but the number of eggs per nest is probably much smaller.

The female very slightly exceeds the male in length from snout to vent but there is no sexual dimorphism in tail length. The tail is so often imperfect and so variable in length that using the total length in determining sexual dimorphism and in making various other comparisons is inadvisable; the snout-to-vent length is, in contrast, highly satisfactory.

Maturity is probably reached at the approximate age of three years. Males attain maturity at a slightly shorter length than females.

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